Surface roughness on rehabilitated slopes

Waste rock dumps and other constructed landforms on minesites typically have outer batter slopes with gradients ranging from 15-35%. As little runoff is retained on such steep gradients, it has become common practice to create some form of surface roughness with the aims of trapping water, improving infiltration and vegetation establishment, and reducing erosion. Approaches range from moonscaping to various forms of cross-slope ripping.

However, observations of rehabilitated slopes lead to the conclusion that in many cases, the surface roughness created has actually **increased** erosion, rather than controlling it.

Common surface roughness treatments – moonscaping (left) and cross-slope ripping (right), showing a typical large rill through the rip lines

The situation is complex, as some treatments may be highly effective in the short term, but quite unstable over longer time periods. Equally, the type of rainfall received in the 12 months following site preparation may determine success or failure, and the potential for a site to be stabilised by vegetation is an issue.

It has been our observation that as surface roughness and its potential to concentrate runoff increases, then so does the potential for gullying on rehabilitated slopes. Both observations and computer simulations indicate that erosion is much higher where runoff is concentrated into a small number of large gullies rather than being spread into numerous small rills.

At this stage, there is insufficient information to identify an optimum surface roughness "treatment" for a range of climates and slope gradients. We view the "bigger is better" approach with concern, as it seems to be typically linked to increased severity of gullying on steep slopes. We regard this topic as an area of minesite practice that would greatly benefit from research information. The cost of some surface roughening treatments is sufficiently high to make this a significant issue.

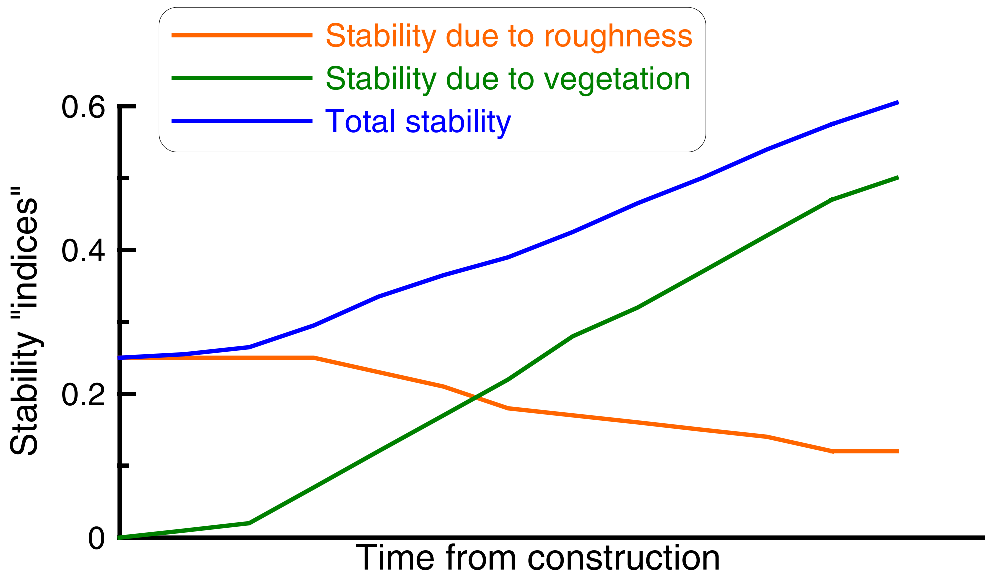
Underlying concepts

Emphasis on surface roughness is based on perceptions that:

- increased surface roughness will reduce runoff and erosion in the short term;

- the additional water trapped and retained by the roughness will increase vegetation establishment and growth; and
- eventually vegetation growth will stabilise the slope.

Graphically, this could be shown as:



Conceptual illustration of "ideal" performance of surface roughness on a rehabilitated slope

However, that idealised perception has little hope of becoming reality if:

- vegetation growth will never produce sufficient surface contact cover to properly stabilise a slope; and/or
- the presence of the roughness actually increases erosion.

For large areas of inland Australia, our observations suggest that surface roughness is unsuccessful for **both** reasons outlined above.

Impacts on vegetation

In general, when an area is roughened, not only does the practice create areas that trap and retain water and sediment, but it also creates excessively steep areas that shed both water and sediment. Therefore, even if the roughening encourages vegetation growth on the 50% of the surface where water ponds, it actually discourages vegetation on the other 50% that is over-steepened. The proportion of surface where vegetation is discouraged appears to increase as riplines become larger.

In some situations, species that are intolerant of waterlogging appear to be suppressed by depressions that trap water and sediment.

There are certainly observations of better vegetation establishment on batter slopes where some surface roughness is applied – paralleling experience in rangeland revegetation over many years. However, it does not necessarily follow from that that exceptionally large roughness patterns will be better still.

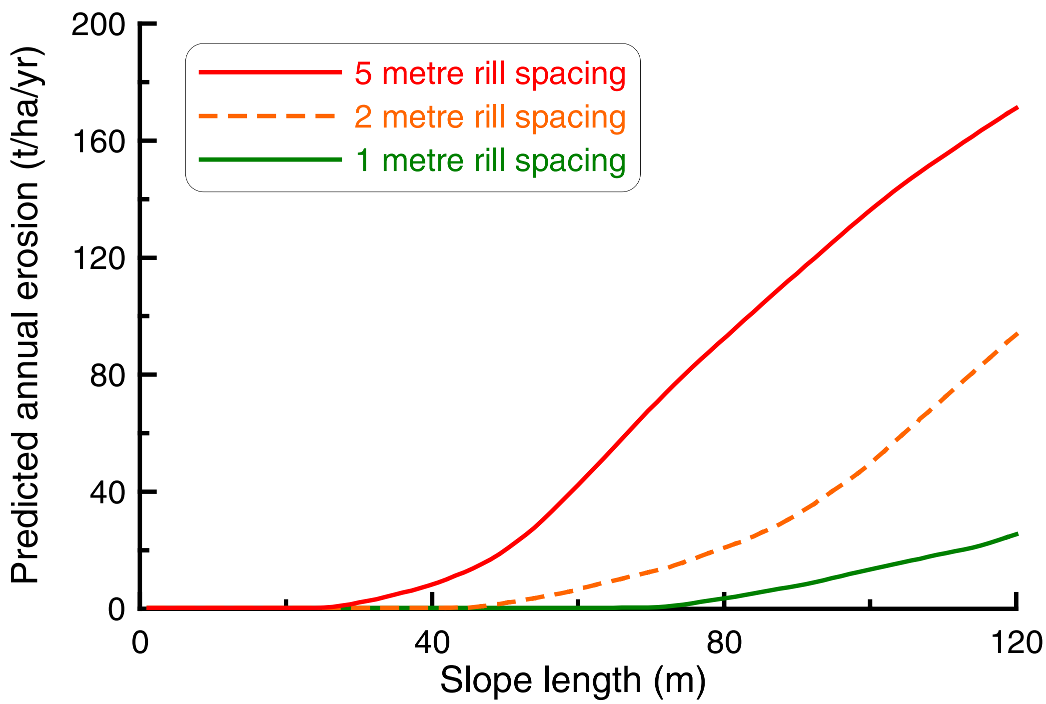
Impacts on runoff and erosion

Freshly-formed surface roughness typically prevents runoff and erosion from occurring at all. But what happens through time?

Generally, the furrows or depressions fill with sediment, and the ridges are worn down by erosion, faunal activity, and weathering. After some time, ranging from months to several years (depending on the stability of the surface material), water ponded in depressions begins to break through and flow downslope. That flow will add to water ponded in the next depression downslope, and overtop it as well. Thus, once one depression "fails", there will be a general failure down the slope and a flow line is created.

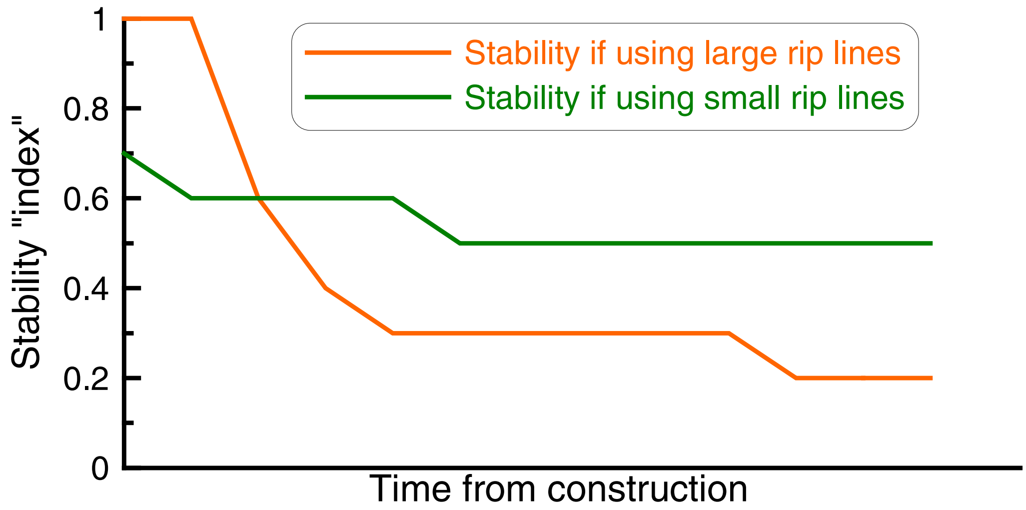
If the furrows and ridges are large, then each break through a rip line may carry runoff from 10 to 30 metres width of slope, and the volume of flow concentrated into one flow line is quite large. Where the furrows and ridges are smaller, breakthroughs are more numerous, and the volumes of flow in each flow line are much smaller.

This can be modeled by varying rill spacing across a slope, and model output indicates that large, widely-spaced rills are far from desirable.



WEPP model simulations for bare spoil with high resistance to rilling placed at 33% gradient, showing effect of rill spacing on erosion rates at points down the slope

The effects of breaks in large rip lines over time is shown in an idealised form in the figure below. It illustrates the rapid loss of stability when large flows break through large roughness elements.



Potential changes through time in stability for two types of surface roughness.

A broader view

Waste rock dumps are very commonly constructed with relatively steep batter slopes (often 20 degree gradient, 10 metres high), separated by berms. The aim is obviously to have short, stable slope lengths, and the figure showing WEPP simulations of slope length and erosion rates illustrates why that approach might be taken.

One could view berms as being simply a larger version of cross-slope ripping.

Like other surface roughness features, berms also tend to “fail”, with the resulting breakthroughs causing gullying, and large increases in erosion. In part, the issue is that surface roughness features, to remain stable, require regular maintenance if they are to remain effective. However, the aim of a rehabilitated minesite is to make maintenance unnecessary.

Conclusions

What we do know is that:

- some surface roughness is useful as an aid to plant establishment
- large surface roughness that can concentrate flows across slope can greatly increase erosion in the longer term.

From that, it would be tempting to suggest that there is some optimum level of surface roughness. However, as the optimum may well vary with rainfall and soil erodibility, it’s unlikely that the answer will be completely straightforward.

It is also clear that this is an area of common practice that drastically lacks information, and some coordinated effort to gather data would be valuable to the industry as a whole.